Union Calendar No. 195

101st Congress, 1st Session - - - - - - - - - - - - House Report 101-310

SETTING PRIORITIES IN SCIENCE AND TECHNOLOGY

REPORT

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

OCTOBER 26, 1989.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

---

U.S. GOVERNMENT PRINTING OFFICE

39-006 WASHINGTON : 1989

H703-11

LETTER OF SUBMITTAL

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC, October 26, 1989.

Hon. THOMAS S. FOLEY,
The Speaker,
U.S. House of Representatives, Washington, DC.

DEAR MR. SPEAKER: By direction of the Committee on Science, Space, and Technology, I hereby submit to you the Committee's report entitled, "Setting Priorities in Science and Technology." The report was approved by the Committee on October 19, 1989. The study and preparation of the report was carried out by the Subcommittee on Science, Research and Technology.

Sincerely,

ROBERT A. ROE, *Chairman.*

Enclosure.

LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
Washington, DC, September 19, 1989.

Hon. ROBERT A. ROE,
Chairman, Committee on Science, Space, and Technology,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: Enclosed is the report, "Setting Priorities in Science and Technology", which has been reviewed by the Subcommittee on Science, Research and Technology. The report results from hearings before the Subcommittee this year which explored mechanisms for evaluating the adequacy of federal funding for science and technology, for determining promising new directions in research, and for establishing priorities in the federal R&D budget.

I believe the recommendations of the report provide useful guidance for improving the process for allocating federal funds for support of science and technology. I request that the report be laid before the Committee for consideration at the earliest convenient time.

Sincerely,

DOUG WALGREN,
Chairman, Subcommittee on
Science, Research and Technology.

Enclosure.

CONTENTS

	Page
I. Introduction	1
II. Recommendations	4
III. The Process of Allocating S&T Funds	5
IV. Role of the Office of Science and Technology Policy	8
V. Establishing Criteria for Evaluating Large Science and Technology Projects	10
VI. Support for Basic Research, University Infrastructure and Science and Mathematics Education	12
VII. Identification of Areas of Science and Technology with the Greatest Potential for Large National Payoffs	14
VIII. Conclusions	16

Union Calendar No. 195

101ST CONGRESS *1st Session* | HOUSE OF REPRESENTATIVES | REPORT 101-310

SETTING PRIORITIES IN SCIENCE AND TECHNOLOGY

OCTOBER 26, 1989.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. ROE, from the Committee on Science, Space, and Technology, submitted the following

REPORT

I. INTRODUCTION

The launching of Sputnik in 1957 highlighted for the Nation the importance of science and technology (S&T) and ushered in a decade of unprecedented federal support for these areas. In the following decade (1967–1977) federal funding, in constant dollars, for research and development (R&D) fell by 20 percent. More recently, federal R&D funding has increased, so that the 1989 federal R&D budget exceeds 65 billion dollars. This represents a 24 percent increase in constant dollars over the peak 1967 levels. However, 90 percent of the estimated federal R&D funding increases that occurred since 1980 are attributable to defense programs.[1] The change in distribution of S&T funds, together with increases in the number and size of the new S&T projects proposed and the severe budget constraints driven by the federal deficit, have led to the present situation in which the federal R&D budget is inadequate to support all the new proposals, as well as to sustain ongoing projects.

These events dictate that, now more than ever before, thorough appraisals and careful planning will be required to maximize the effectiveness of the federal funds available for R&D. This is not a simple task. The federal FY1989 R&D budget is divided between more than 10 different Executive Branch departments and agencies. During the budget process the funding requests of each agency and department are considered separately by the Office of Manage-

[1] *National Patterns of R&D Resources: 1989,* report of the National Science Foundation, (Washington, DC, 1989), NSF89-308.

ment and Budget (OMB), and only after this process is completed is the total R&D budget integrated in a special analysis of research and development, an appendix to the President's budget.[2] In Congress, the budget process is even more fragmented with responsibility for S&T divided among 15 House and Senate Committees.

Most observers believe that the pluralistic and decentralized nature of the federal S&T effort has contributed to its strength, but it also has made coordination and prioritization of federal S&T programs difficult. The Office of Science and Technology Policy (OSTP) was created by the National Science and Technology Policy Organization and Priorities Act of 1976, Public Law 94-282, to improve coordination and to assist the President with S&T policy decisions. Public Law 94-282 gave OSTP broad coordination, oversight and planning responsibilities. These responsibilities included assisting the President during the budget process, developing and recommending criteria for determining scientific and technological activities warranting federal support, and identifying and assessing emerging and future areas in which S&T can be used effectively in addressing national problems.

Unfortunately, the resources and personnel available to the Director of OSTP have been limited. A 1988 hearing [3] of the Subcommittee on Science, Research and Technology revealed that OSTP has had difficulty fulfilling the broad goals outlined in Public Law 94-282. Witnesses, including several former Presidential Science Advisors, felt that the budget and the staff of OSTP should be increased to the levels comparable to those of the former Office of Science and Technology (OST) which existed from 1962 to 1973 and had a similar mission.

In 1982, following a decade of decreased or level science funding, a hearing on Setting Priorities in Science [4] investigated how the greater public interest could be reflected in federal R&D choices and other related issues. Witnesses from federal agencies and departments, academe, industry and state governments discussed the need to set science priorities, how the priorities of federal agencies and industry were established, and the problems inherent in choosing among fields. This hearing served as an overview of many of the issues involved in priority setting for science, but a consensus was not reached on specific recommendations for changes in the process of setting priorities.

Several recent circumstances have underscored the need for a reexamination of the process by which the federal S&T budget is evaluated and prioritized. The most prominent of these is the current budget deficit, which does not allow full funding of all the meritorious R&D projects that have been proposed. The effects of the budgetary constraints imposed by the deficit have been exacerbated by the increasing number of large science projects which

---

[2] *Analysis of Research and Development* in the Special Analysis of the Budget of the United States Government, Office of Management and Budget, Executive Office of the President.

[3] Hearing before the Subcommittee on Science, Research and Technology of the House Science, Space and Technology Committee on *Oversight of the Office of Science and Technology Policy*, 106, 100th Congress, 1988.

[4] Hearing before the Subcommittee on Science, Research and Technology and the Subcommittee on Investigations and Oversight of the House Science and Technology Committee on *Science and Technology on Setting Priorities for Science*, 172, 97th Congress, 1982.

have been funded, each requiring the allocation of substantial federal funds over many years. This situation, therefore, threatens to overwhelm the rest of the S&T budget and effectively establishes budgetary priorities for years to come. In addition, heightened international competition has demonstrated that the U.S. can no longer take its technological leadership for granted and that our limited R&D resources must be allocated to support endeavors that are likely to provide the largest payoffs.

These factors which indicate that hard choices will have to be made led to a request in the Conference Report accompanying the Concurrent Resolution on the Budget for FY 1989 [5]

> . . . that the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine provide advice on developing an appropriate institutional framework and information base for conducting cross-program development and review of the nation's research and development programs. This should be structured in such a way that it can be used by both the Executive Branch and Congress as a method for reviewing program contents and strategies and in determining funding and organizational priorities for science and technology.

The resulting report entitled, *Federal Science and Technology Budget Priorities: New Perspectives and Procedures,* was completed in December, 1988, [6] and made a number of recommendations which will be discussed subsequently.

On February 28 and March 1, 1989, the Subcommittee on Science, Research and Technology held a hearing investigating the adequacy, direction and priorities of S&T in this country. The main objective of the hearing was to identify mechanisms for evaluating the adequacy of funding support of science and technology, for determining promising new directions in research, and for establishing priorities in the federal R&D budget.[7] A list of the witnesses is included in Appendix I.

The following issues were explored during the hearing: 1) the process of allocating S&T funds among different fields of science and technology, 2) the role of OSTP in the budget process, 3) establishment of a set of formal criteria for evaluating big science projects, 4) the adequacy of support for basic science and engineering research, university research infrastructure, and math, science and engineering education, and 5) the identification of S&T research areas which have the greatest promise for providing public benefits. This report discusses each of these issues primarily on the basis of testimony presented at the hearing.

---

[5] *Conference Report* on the concurrent Resolution on the Budget for Fiscal Year 1989 to accompany the H. Con. Res. 268, House Report 100–658, 1988.

[6] *Federal Science and Technology Budget Priorities: New Perspectives and Procedures,* report of the National Academy of Science, the National Academy of Engineering and the Institute of Medicine (National Academy Press, Washington DC 1989).

[7] Hearing before the Subcommittee on Science, Research and Technology of the House Science, Space and Technology Committee on *The Adequacy, Direction and Priorities of the American Science and Technology Effort,* 7, 101st Congress, 1989.

II. RECOMMENDATIONS

The Committee recommends that the President appoint four Associate Directors with the advice and consent of the Senate to the Office of Science and Technology Policy as set forth in Public Law 94-282. In addition, a full complement of professional staff with expertise in a broad range of science and technology should be appointed to ensure that OSTP can pursue the range of functions mandated by statute, especially responsibilities in assisting the Office of Management and Budget and the President during the formulation of the S&T budget.

A. The Committee recommends that the Executive Branch, beginning with the preparation of the FY 1992 budget, implement the following suggestions of the National Research Council report, *Federal Science and Technology Budget Priorities:*

(1) The President's objectives in the cross-cutting S&T areas should be included in initial OMB instructions to the agencies for preparation of their budgets, and these priorities should guide the formulation of the President's final budget proposal to Congress.

(2) The President's budget submission to Congress should contain a statement of the Administration's priorities for the S&T base, S&T activities serving national objectives, and major S&T initiatives, as well as a summary of agencies' mission-related S&T activities.

B. The Committee recommends that the President's statement of priorities for the S&T base contain a breakdown of federal funding in two areas of particular importance:

(1) Support for science, mathematics and engineering education at all levels—K through graduate school.

(2) Support for basic science and engineering research and for university research facilities.

These areas provide the foundation upon which the rest of the Nation's S&T efforts are built and, therefore, the funding levels for these areas should be reviewed annually.

C. The Committee recommends that OSTP assemble a group of experts to determine the components of the Department of Defense (DOD) R&D effort that also address civilian S&T needs and therefore would be appropriate to include in estimates of the national S&T effort overall.

D. In addition, the Committee recommends that OSTP, in conjunction with OMB, establish a procedure for agencies to use in analyzing the budgetary impact and scientific contribution of proposed large science and technology initiatives that would have a major effect on the S&T budget. The procedure should include, as a minimum, a consistent set of predetermined criteria to assess scientific merit, social benefits, and programmatic concerns, especially multi-year impact on the R&D budget. The evaluation and ranking of proposed large S&T initiatives should be accomplished sufficiently early in the budget process so that the results can be reflected in OMB's guidance to the federal agencies on S&T priorities.

In the event that the preceding recommendation is not implemented, the Committee will consider requesting agencies within its jurisdiction to submit, as a part of the budget request, an analysis

of major S&T initiatives using a predetermined set of criteria. These data would be used to establish a procedure to prioritize these major S&T initiatives relative to the S&T resources available within the Committee's jurisdiction.

The Committee recommends that OSTP test the usefulness of a Delphi-like process to be carried out on a recurring basis to determine a consensus view on new and emerging areas of technology having the potential for large payoffs that could contribute to national competitiveness, public health, national defense, or other public benefits. The Delphi-like process should focus on applied research and development; should involve representatives from industry, academe, and government; and should result in findings that are incorporated into the priority setting process as the President's budget is formulated.

III. THE PROCESS OF ALLOCATING S&T FUNDS

At the start of the annual budget process, federal agencies and departments establish priorities and assemble related budget estimates. These budget estimates are then submitted to the Office of Management and Budget (OMB) where they are considered separately by six different divisions. After negotiating the final budget adjustments with each agency, OMB compiles the Presidents' Budget. Only after the budget is formulated is the total federal R&D budget summarized and broken down into R&D programs by agency in a special analysis of research and development.

This type of agency approach to R&D budgeting is fragmented. The special analysis of the R&D budget is of limited use because it is formulated *after* the OMB budget process is completed. The single exception in the FY 1990 budget request was the global change initiative. The initiative was developed by the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) and documented in the report, *Our Changing Planet: A U.S. Strategy for Global Change Research,*[8] which accompanied the budget. The global change initiative represents a cross-cutting analysis of an area of R&D developed as part of the budget process and amply demonstrates that this type of analysis of R&D areas that overlap a number of agencies can be accomplished effectively.

During the Subcommittee hearing, Dr. Robert White, the President of the National Academy of Engineering, presented the recommendations of the recent National Academies' report addressing the federal budget process. The report recommended that federal S&T expenditures be grouped into four categories related to the national purposes that they serve: S&T in the context of agency missions, the S&T base, S&T in relation to national objectives, and major S&T initiatives. The report also suggested several procedural changes in the budget process of both the Executive Branch and the Legislative Branch that would allow a cross-cutting analysis of the total S&T budget without producing major changes in the budget process. These suggestions included:

---

[8] *Our Changing Planet: A U.S. Strategy for Global Change Research,* report by the Committee on Earth Science of the Federal Coordinating Council for Science, Engineering, and Technology to accompany the U.S. President's FY 1990 budget (Washington, DC, 1989).

(1) The President's objectives in the cross-cutting S&T areas should be included in initial OMB instructions to agencies for the preparation of their budgets, and these priorities should guide the formulation of the President's final budget proposal to Congress.

(2) The President's budget submission to Congress should contain a statement of his priorities for the S&T base, S&T activities serving national objectives and major S&T initiatives as well as a summary of agencies' mission-related S&T activities.

(3) The congressional budget and appropriations committees should conduct reviews of cross-cutting S&T activities and incorporate their judgments into recommendations for agency budget allocations.

(4) Following the enactment of necessary authorizations and appropriations, the Executive Office of the President should work with agency heads to see that S&T programs are carried out in accordance with the President's priorities as modified by Congress.

In addition to the above suggestions, the National Academies' report recommended that a group of experts be assembled to examine what DOD activities should be appropriately classified as R&D for purposes of reporting federal resource allocations for R&D. This recommendation was based on the observations that DOD funding accounts for about two-thirds of federal R&D support and that more than 75 percent of these DOD funds:

> . . . are for advanced technology and military equipment development, testing and evaluation and the operation of facilities for these specialized purposes-activities that are critical to the DOD but not comparable to other federal agencies. Lumping together as R&D the defense and civilian agency activities now classified as such may lead to overstating the national S&T effort overall and in certain research fields.

In his testimony, Dr. Branscomb also addressed the issue of the way the Nation's total R&D effort is estimated when he asked, "Which of these measures: total R&D or non-defense R&D divided by GNP, is a more appropriate basis for comparing the adequacy of U.S. investments with competitors?" He concluded that, "To the extent research results are difficult to transfer and are most effectively employed in the institutions that do the work . . . the second measure is more appropriate, and the U.S. seems to be underinvesting, compared to Japan."

Most witnesses acknowledged that the process of prioritizing and coordinating the federal S&T effort could be improved. Commenting on the Academies' report, Dr. Cyert noted that, " . . . the major points that the individuals from the Academy have made are excellent." Dr. Branscomb stated that:

> This document is an excellent beginning for addressing the issues . . . the document proposes a process that in no way diminishes the responsibility of the OMB, but greatly increases the likelihood that the President will see a

> more balanced and coherent science and technology program . . .

Despite the wide agreement among witnesses that a coherent S&T policy requires coordination and cross-cutting analysis of the S&T budget, witnesses also underscored the importance of retaining decentralized decision-making in S&T whenever appropriate. This view was stressed by Dr. Mary Good when she stated that a " . . . major contribution to our national vitality in science and technology has been our diversity of objectives. However, I believe that diversity can be maintained within a framework of a coordinated effort." The recommendations of the National Academies provide for early cross-cutting reviews, while retaining the decentralized nature of the Federal S&T effort.

During the hearing, both Dr. Keyworth and Mr. Carey suggested more substantial organizational changes. Dr. Keyworth proposed the formation of a Department of Science and Technology to " . . . focus attention on that half of American's total R&D that the governments policies dictate . . . By putting together a coherent program out of a single budget, with visible means of accountability to the Congress and to the public, and it would force us to make the kind of trade-offs that are sometimes avoided in this current diversity we have now." On the other hand, Mr. Carey emphasized that " . . . we have no way of articulating Government's efforts in R&D with efforts in industry . . . " and he suggested the formation of a civilian Defense Advanced Research Projects Agency (DARPA). Similar recommendations have been made by other science policy commentators over the years.

The other witnesses that commented on the changes suggested by Dr. Keyworth and Mr. Carey were skeptical about their usefulness. This skepticism was evident in Dr. Good's statement that:

> . . . the organizational structure that we presently have can work, and my problem with a Department of Science and Technology is that, number one, it would take too long to get it in place, and I don't think we have time to do that . . . I think that you can take the structure we presently have. I think you can encourage people in those positions, and, in fact, the Congress can request that budgets come in certain formats . . .

Dr. Brinkman felt that the scope of the proposed Department of Science and Technology, which would exclude both biomedical and defense R&D funding, would be too narrow to accomplish the goal of improving planning and priority setting in S&T.

The National Academies' report also discussed the growing support for biennial budgeting concluding that it would allow " . . . program managers to plan their S&T activities over a longer period . . . and it would encourage decisionmakers to be more realistic about out-year spending requirements especially for major projects." The concept of multi-year authorizations has been supported by the General Accounting Office (GAO),[9] the Office of

---

[9] *U.S. Science and Engineering Base: A Synthesis of Concerns About Budget and Policy Development*, staff study by the General Accounting Office, (Washington, DC, 1987), GAO/RCED-87-65.

Technology Asssessment (OTA), and the Congressional Budget Office (CBO).

Biennial budgeting was also supported by Mr. Carey, who felt that it would " . . . build enough time into the process [of budgeting] to make it workable".[10]

IV. ROLE OF OFFICE OF SCIENCE AND TECHNOLOGY POLICY

The science and technology arena has increased in size and complexity since 1951 when William T. Golden, in a review of military scientific research for President Truman, recommended the appointment of a scientific advisor to the President to be assisted by a science advisory committee. In 1957, following the shock of Sputnik, this suggestion was fully implemented with the appointment of Dr. James Killian as the President's Science Advisor and the establishment of a Presidents' Science Advisory Committee and the Office of Science and Technology (OST) by President Eisenhower. These organizations oversaw the rapid and very successful expansion of federal support for science and technology in the post-Sputnik era. With a brief hiatus between 1973 and 1976, following the disbandment of OST and elimination of the position of the President's Science Advisor by President Nixon, the nation has had a science advisory office and a Presidential Science Advisor for more than three decades.

In 1976, Congress, believing that a science advisory office in the Executive Branch was essential for effective coordination and planning of S&T, enacted Public Law 94-282, which replaced the disbanded OST with a new Office of Science and Technology Policy (OSTP). The legislation was crafted in full consultation with the Ford Administration because Congress was well aware that the ultimate effectiveness of the office would depend on the President's willingness to use it. The Director of OSTP was not statutorily designated as Science and Technology Advisor to the President, but was authorized to advise the President on S&T issues and to serve as Chairman of the FCCSET, also created by the legislation to coordinate the activities of the federal R&D agencies in meeting national objectives. By creating OSTP through statute, Congress eliminated the possibility that OSTP would suffer the same fate as OST.[11]

Public Law 94-282 charged the Director of OSTP with: (1) advising the President of scientific and technological considerations involved in areas of national concern; (2) evaluating the scale, quality and effectiveness of the Federal S&T effort; (3) advising the President on S&T considerations with regard to the federal budget and assisting the Office of Management and Budget (OMB) with an annual review; and (4) assisting in providing leadership and coordination in federal R&D programs.

---

[10] The House Committee on Science, Space, and Technology mandated three-year budget requests, beginning with the FY 1990 budget, be submitted by the National Science Foundation and the National Institute of Standards and Technology. However, in responding to the multiyear authorization requests, the agencies submitted budgets reflecting incremental increases for the outyears based on the first fiscal year of the budget submission rather than on established priorities for each of the fiscal years. This has not fulfilled the Committee's intent that the outyear budgets should reflect future priorities.

[11] Knezo, Genevieve, *Analysis of the Office of Science and Technology Policy,* Congressional Research Service Report for Congress, (Washington DC, 1988) CRS88-205.

In 1982, the OSTP Director created the White House Science Council (WHSC) to help assess major policy issues and to provide advice to OSTP. The WHSC has been criticized for not being an effective policy making body because it is advisory to the Director of OSTP, not to the President;[12] and, thus, membership is not subject to congressional nominating procedures or oversight. For this reason, science policy observers have supported the reestablishment of a President's Science Advisory Committee which is independent of OSTP, similar to the one existing prior to 1973.

The view that OSTP has been unable to execute the broad S&T policy and coordination responsibilities outlined in Public Law 94-282 has been more prevalent in recent years. In particular, the perception exists that OSTP has failed to provide the needed long-range planning required to develop a coherent national R&D effort and that coordination between federal agencies, in most cases, is suboptimal. These deficiencies may be attributed to the decrease in permanent staff that has occurred in OSTP in recent years.[13] In 1987, only 7 of the 30 full-time professionals at OSTP were permanent staff and all other staff were detailees from other agencies.

A similar perspective of OSTP's effectiveness was repeated by witnesses during the hearing. Although Dr. Keyworth, a former Presidential Science Advisor, testified, ". . . that the inordinate amount of attention paid to things like the status of the science advisor or the number of people on his staff have wasted intellectual and political capital . . .," it was particularly noteworthy that as a former Science Advisor and the Director of OSTP he felt that ". . . we didn't and don't go anywhere near far enough . . . optimizing a national R&D program."

Despite the past performance of OSTP, most observers of S&T policy agree that the President's Science Advisor and OSTP should play a more prominent and major role in the prioritization and budgeting process for S&T.[14] For example, the National Academies' report states that, "We believe that the President's Science and Technology Adviser, working closely with the director and professional staff of OMB, is best suited to coordinate both phases of this [the budget] process." This view was repeated by a number of the witnesses, including Dr. Good who stated, "Presently, the best group to convene and coordinate a strategic planning group is the Office of Science and Technology Policy."

In particular, witnesses stressed the continued need for OSTP to play a major role in the budget process. Mr. Carey, a former Assistant Director of the Bureau of the Budget, emphasized that, "OMB needs the technical expertise of OSTP in constructing outcomes that in fact will constitute both good science and technology policy and articulate Presidential preferences and support." Mr. Carey went on to state that to do this, ". . . adequate staffing is necessary in OSTP . . . [and] a seat at the OMB's budget review table for the principal officers of OSTP."

---

[12] Golden, William, *President's Science Advisory Committee Revisited,* in Science, Technology and Human Values (John Wiley & Sons, NY, 1986) 11:5.

[13] Knezo, Genevieve, *Analysis of the Office of Science and Technology* Policy, CRS88-205, 1988.

[14] Golden, William, *Science and Technology Advice to the President, Congress and Judiciary* (Pergamon Press, N.Y. 1987).

The estimated FY 1990 budget for OSTP is $1,407,000, which represents a decrease of 65 percent in constant dollars from the peak funding level which was in FY 1979. It is ironic that this decline has occurred during a period when science and technology has permeated all facets of our society. Today, we face monumental challenges in the areas of health, environmental protection, and economic competition. Crucial decisions in these and other areas will require expert scientific and technological advice. Funding and staffing levels for OSTP must support an organization with both sufficient depth and breadth to address these diverse issues.

V. ESTABLISHING CRITERIA FOR EVALUATING LARGE SCIENCE AND TECHNOLOGY PROJECTS

The unprecedented growth of large science and technology initiatives that require substantial federal funding for many years has magnified the shortcomings of the federal S&T budget process. These large initiatives will drive R&D resource allocations by their sponsoring agencies over several years. The real cost of these large projects is not just the direct funding of the initiative, but also the opportunity cost of all the other research that will go unfunded. The demands that these projects impose on the budget require that they be scrutinized carefully. Unfortunately, as noted by Dr. Branscomb, "The rigor with which the technical benefits from new projects are assessed seems to vary inversely with the size of the project." [15] Changes in the budget process are necessary to ensure that a thorough evaluation of new initiatives is undertaken by the Executive Branch and the Legislative Branch. This evaluation should occur early in the budget process since, once a project is underway, considerations other than scientific and technological merit (i.e. effect on local economies, etc.) may bias the technical evaluation process. The National Academies' report briefly discussed the evaluation of large science projects and stated that,

> The analyses of special intitatives with large budget consequences should identify how the proposed program contributes to . . . mission agency objectives; the S&T base; and social, economic and other objectives. The analyses also should consider impacts of the program on other S&T activities.

A formal system, that would provide the Executive Branch and Congress with advice on the prioritization of large science projects and that incorporates similar evaluation criteria as that mentioned in the National Academies' report, has been developed by Drs. Crowe and Dutton.[16] Dr. Crowe summarized this system at the hearing and stated that it ". . . diminishes the effects of hidden agendas and covert self-interest." The Crowe and Dutton system includes many of the yardsticks formulated to evaluate large science projects by Dr. Alvin Weinberg, former Director of Oak Ridge National Laboratory, following his involvement in the debate about

---

[15] Hearing before Senate Budget Committee on *Science and Technology*, 578, 100th Congress, 1988.

[16] Dutton, John and Lawson Crowe, *Setting Priorities Among Scientific Initiatives*, American Scientist (1988) 76:599.

funding the manned moon mission in the early 1960's.[17] In testimony before the Subcommittee,[18] he stated that,

> For the really large decisions—whether to build a 1000 GEV accelerator or a space telescope—I suggested that criteria internal to science and derived from the intrinsic logic of science were insufficient. For such decisions, criteria external to science or to a given field of science, were necessary.

The system proposed by Dutton and Crowe specifies three categories of criteria for evaluation of scientific initiatives with a set of specific questions posed for each criterion. Proposals for new initiatives would be required to include answers to these questions, thereby permitting a systematic prioritization of competing projects. The three categories of criteria are scientific merit, social benefits, and programmatic concerns. Scientific merit encompasses the project's objectives and significance, its breadth of interest, its potential for new discoveries, and its uniqueness. Social benefits would include contributions to human welfare, economic growth, national defense, national prestige and international understanding. Programmatic concerns would include such issues as feasibility, logistics and infrastructure, institutional implications, and international involvement.

Dr. Crowe noted that, ". . . initiatives scoring highest in all three of the broad categories of evaluation criteria are most likely to be attractive at the national level." However, he stated that reviewers may give different weights to the three categories of criteria. For example, Dr. Good emphasized the importance of international cooperation in large science projects in her statement that ". . . the time has come where other industrialized nations should carry a significant fraction of the resource burden for large science projects."

In his testimony, Dr. Crowe concluded that the relatively homogeneous documentation that will result from a list of specific questions in each area should facilitate a meaningful comparison of "large" science projects. He stated that:

> Dr. Dutton has applied this procedure successfully with two high-level advisory committees, one at NASA [National Aeronautics and Space Administration] and the other at the NSF-Universities Corporation for Atmospheric Research long-range planning committee. This latter application was especially notable since it involved consideration of multidisciplinary long-term initiatives in atmospheric sciences.

When asked during the hearing how the scientific community views this proposal, Dr. Crowe responded that, " . . . skepticism . . . is a pretty general reaction. There is also a fear that something like centralized decisionmaking might issue from such activity." Dr. Branscomb expressed this view when he commented that:

---

[17] Weinberg, Alvin, *Criteria for Scientific Choice*, Minerva (1963) 1:159.
[18] Hearing on *Setting Priorities for Science*, 172, 97th Congress.

> My skepticism about Professor Crowe's suggestion is that while I do not disagree at all with his criteria, I am very nervous about asking the scientific community to make judgments which in the normal course of events our representatives in Congress and our elected officials in Government are supposed to make about the relative importance of the Federal role in bolstering the economy versus defending ourselves against potential hostile nations, versus improving the public health and many objectives.

Nevertheless, in response to a follow-up question on the value of the Dutton and Crowe approach, Dr. Branscomb supported the implementation of such a process and suggested that, "the process should be open to public view, should be supported by adequate documentation and should be conducted under the authority of the Congress, by an executive agency such as OSTP, but using the institutional capabilities of an established and credible institution such as NAS/NAE." But he stressed that, "such an evaluation can only be advisory to government, and will be no stronger than the wisdom and maturity of the people evaluating the evidence and the credibility of the institution that stands behind them."

Dr. Mary Good agreed that, " . . . if review criteria were in place before the process begins . . . such a review could be extremely beneficial". If scientists do not participate, then, " . . . without . . . advice . . . the Congress will have little choice but to make . . . decisions without formal guidance on priorities from experts in the scientific community, and the scientific community will have no choice but to accept the results." [19]

VI. SUPPORT FOR BASIC RESEARCH, UNIVERSITY INFRASTRUCTURE AND SCIENCE AND MATHEMATICS EDUCATION

The Nation's scientific and technological effort depends on an adequate supply of scientists and engineers, a technologically literate workforce and a steady stream of basic scientific findings that can be translated into technological innovations. This requires adequate and sustained federal support for the science base, which includes basic research support, science, math and engineering education at all levels, and university infrastructure.

For these reasons, Dr. Frank Press, the President of the National Academy of Sciences, recommended in a speech on the issue of priorities in science and technology [20] that, "above all the science base must be maintained and strengthened." He stressed:

> This means absolute priority for training and research grants reaching the largest number of scientists, engineers, clinical researchers. This encompasses the funding of research universities and national laboratories reaching the largest number of investigators and graduate students.

---

[19] Baldwin, Elizabeth and Chris Hill, "The Budget Process and Large-Scale Science Funding", in the *Major Issues Forum on Science and the Budget*, Congressional Research Service (Washington, DC, 1988) 9:2.

[20] Press, Frank, "The Dilemma of the Golden Age", address to members of 125th Annual Meeting of National Academy of Sciences, April 1988.

The importance of adequate federal support for the science base also was emphasized by most of the witnesses and was evident when Dr. White stated, " . . . it is the responsibility of the United States Government to support basic science . . ." In discussing the importance of the "preservation of basic science in a federal process that is placing increasing emphasis on issues such as competitiveness", Dr. Brinkman emphasized that, " . . . it is easy to allow the urgency of economic competitiveness in the near term to override the importance of long-term relatively undirected basic research . . ." Likewise, Dr. Cyert noted that, "One characteristic of our society at this point is it really is a knowledge-based society . . . it is true that for the long run those countries who have a pool of knowledge to which there can be access are going to . . . maintain strong positions. So that we need to continue to develop this pool of knowledge through a support of basic research . . ."

A vigorous science establishment requires a literate and scientifically knowledgeable population from which the future supply of scientists and engineers can be recruited. Dr. White noted that the Academy of Engineering recently issued a statement on the question of technology competitiveness [21] which concluded that, ". . . we believe it is important for the government to be very deeply involved in the question of education. We cannot be competitive over the long run—and this is recognized by everybody—unless we have a vital, vigorous educational system going all the way from beginning, right up to the university system".

Unfortunately, as stated by Dr. Good at the hearing, ". . . we are facing an educational crisis where the public literacy and technical capability is not adequate to maintain the technologically based infrastructure of the twenty-first century. The science and math scores of our children are alarmingly poor, and the number of U.S. citizens choosing to pursue scientific and engineering careers is steadily decreasing." This trend combined with the fact that the majority of the new entrants into the workforce in 2020 will be composed of women and minorities, two groups that traditionally have been underrepresented in science and math, indicate that our Nation may face a serious shortage in our scientific and technological workforce.[22]

It is noteworthy that Dr. Pollard, who participated in a panel of witnesses testifying on the adequacy of support for university-based research, chose instead to focus on primary and secondary education because, "no matter how many dollars are available for the elite to do their research at the university level, the country will fail to compete economically and militarily if our basic educational system is rotten . . . Our generation is presently presiding over the decay of our educational system . . . We as a people need to make an immediate, large investment in education . . ." Similarly stressing the importance of education, Dr. Good suggested that, "Every federal R&D project should have an educational component . . ." Efforts aimed at improving science, mathematics and engineering

[21] *Technology and Competitiveness,* statement of the Council, National Academy of Engineering, January 1989.

[22] *Educating Scientists and Engineers: Grade School to Grad School,* report of Office of Technology Assessment, Congress of the United States, June, 1988.

education have increased, but the consensus view among the witnesses at this hearing and other recent hearings of the Committee on Science, Space, and Technology [23] was that further effort is still needed to avert the crisis in human resources that we will face early in the 21st century.

The importance of university research in the training of future scientists and engineers was reiterated by Dr. Brinkman who stated that, "University research plays a very, very important tole in training people, and the Federal Government is still the major funding source for that. So we need to continue to see to it that it it healthy." University-based scientists who testified indicated that the funding for basic science varied considerably between fields, and that certain fields were clearly underfunded. For example, Dr. Fefferman, a Professor of Mathematics at Princeton University, cited the recommendations of a 1984 National Academy of Sciences report,[24] which concluded that the funding level for senior investigators in mathematics was deficient and recommended funding increases, and commented that these recommendation have still not been implemented.

In addition to individual support for university researchers, support for university infrastructure—equipment, facilities and libraries—is needed to maintain excellent training for both undergraduates and graduate students in science and engineering. It was emphasized by Dr. Branscomb that the:

> U.S. government R&D system is unbalanced in the direction of short-term and wishful thinking. Needed capital investments in new tools, and the renovation of facilities . . . are too often postponed . . . buildings should be renovated every few years if it would enhance research productivity. This rarely happens in universities or government laboratories.

VII. IDENTIFICATION OF AREAS OF SCIENCE AND TECHNOLOGY WITH THE GREATEST POTENTIAL FOR LARGE NATIONAL PAYOFFS

The escalation in international competition combined with the current budgetary constraints make it more important than ever that the federal funds supporting technological development and innovation are spent wisely. This means encouraging the transfer of basic research into technology and commercial applications and identifying areas of S&T with the potential for the large national payoffs.

Although OSTP has the responsibility for both long-range planning and forecasting, it has primarily concentrated on addressing the day-to-day concerns of the White House. The S&T report and outlook that OSTP is required to submit to Congress on January 15th of each odd-numbered year, is mandated to include, among other things, a forecast of emerging S&T issues. Unfortunately, this report has often been late and outdated, and the prevailing view has been that, even when completed, these reports have been

---

[23] Hearings before the Committee on Science, Space, and Technology on *Science and Mathematics Education.* 101st Congress, 1989.

[24] *Renewing U.S. Mathematics: Critical Resources for the Future,* report of the Committee on Physics, Mathematics and Resources (National Academy Press, Washington DC, 1984).

deficient in terms of long-range planning and forecasting. The latest Science and Technology Report and Outlook [25] contains a chapter on the Outlook in Selected Areas of Science and Engineering, summarizing the information derived from research briefings provided to OSTP by the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academies.

The importance of forecasting was emphasized by Dr. Cyert during his testimony. He discussed the need for government leadership in initiating a process to identify and prioritize promising technologies and suggested that a Delphi [26] process could be used to determine a consensus view of which future areas of technology will provide large national payoffs. He noted that Japan has successfully used this type of consensus building procedure to obtain agreement on areas of S&T that should be emphasized.

Other witnesses agreed that it was important to identify new areas of technology having the potential for large payoffs and that a Delphi process might be an appropriate way to accomplish this task. However, they were cautious about its use. Dr. Good, discussing the difficulties which are inherent in any forecasting process, stated:

> The problem of identifying and prioritizing new areas of technology is that our crystal ball is for the most part not good enough. For example, I do not believe that we would have identified either high temperature superconductors or low temperature fusion as new areas of research and development . . . There are other areas where technologies have been clearly identified which do indeed impact the national position. One of these is high density TV. This is obviously an area where we must have leadership or at least a competitive position, since it impacts on our commercial success as well as our defensive position. A Delphi-like process could be indeed used to determine those areas of technology which have the best potentials for national impact. This would mean that choices would be between those areas which have already been identified and where a vision of their ultimate potential can be seen. A Delphi-like process to determine areas of basic research, for the most part, in my opinion, would be futile since basic research by its definition is the activity where totally new and unexpected ideas arise.

However, she concluded that "Delphi groups should be carefully chosen and kept relatively small."

Dr. Branscomb also discussed the limitations of such a procedure stating:

> . . . most Delphi studies feedback fads of the day and are very poor at predicting surprises. They are perhaps a

---

[25] *Science and Policy Report and Outlook—1985-1988,* report of the Office of Science and Technology Policy in cooperation with the National Science Foundation (Washington, DC, 1989).

[26] The Delphi process is a technique used to gather and process information and judgement from a group of individuals who are experts in a particular field or subject. All Delphi exercises share three basic characteristics, use of controlled feedback, use of sequential questionnaire (usually three rounds), and preservation of the anonymity of the respondents. Delphi is often preferred to conferences because it reduces the dominance of certain individuals, eliminates group pressure to conform, and eliminates the bandwagon effect of majority opinion.

> useful way to test the extent of departure from consensus of matters of judgement. In this case, it is really important to know the extent to which there is a consensus in industry on what the country needs, in technology, science, education and infrastructure, to make us more competitive.

Thus, a Delphi-like process may be useful in targeting technologies ripe for exploitation, with the caveat that it is likely to exclude some important new directions and, therefore, should be used cautiously.

A clear theme which emerged during the Subcommittee hearing was that the highest priority for the federal S&T effort should be to increase our national competitiveness because, as stated by Dr. Good, "All of our goals flow from it. If we cannot maintain a competitive position where our businesses are strong and provide appropriate jobs for our people, none of our other goals are achievable." In discussing the issue of technology and competitiveness Dr. White commented that the National Academy of Engineering sees:

> . . . a role for the federal government in the support of the civil technology base itself. And that role relates to those areas of technology where, if for one reason or another, market forces cannot put in the resources and investment to enable us to keep up with our trading patners and commercial competitors.

According to Dr. Keyworth, one of our main weaknesses has been the culture gap between universities and industry which hampers the transfer of technology. Both Dr. Cyert and Mr. Hecht emphasized that the federal government can reduce this gap by promoting university-industry-government consortia which foster technology transfer. In addition, Dr. Waymouth noted that, "the establishment of NSF engineering centers and technological centers in universities is a step in the right direction to bring the needs of industry to the attention of academic researchers." Several witnesses also stressed that the national laboratories should be mobilized for the development of technologies having high potential for commercial exploitation.

VIII. CONCLUSIONS

The areas of consensus that emerged from the hearing are reflected in the recommendations of this report. The need for an assessment of federal S&T budget priorities across agency boundaries was strongly endorsed. The importance of instituting standardized evaluation procedures for multi-year initiatives, which create large mortgages that must be accommodated in future S&T budgets, was also stressed. OSTP was identified as the Executive Branch organization which should assume the central role in the formulation of overall S&T budget priorities, as well as in carrying out assessments of long-term technology trends and opportunities. In order to fulfill these roles, OSTP was viewed as requiring a professional staffing level greater than that which has prevailed during most of the history of the Office.

In addition to the process of priority setting, the hearing also generated suggestions of specific priority areas for expenditure of

federal S&T funds. The necessity for overcoming the deficiencies apparent in science and mathematics education in the Nation's schools was stressed, as was the importance of sustaining support for basic science and engineering research and for the associated university-based research infrastructure. Equally strong was the view that research and development activities which contribute to increased economic competitiveness should be afforded the highest priority in allocation of S&T resources, since growth of national wealth ultimately underpins achievement of all other S&T goals.

APPENDIX 1

Witness List: Hearing before the Subcommittee on Science, Research and Technology, "The Adequacy, Direction and Priorities of the American Science and Technology Effort". (In Order of Appearance.):

Dr. Robert White, President, National Academy of Engineering;

Dr. Lewis Branscomb, Director, Science, Technology and Public Policy Program, John F. Kennedy School of Government, Harvard University;

Dr. Richard Cyert, President, Carnegie-Mellon University;

Dr. Lawson Crowe, Professor, Department of Philosophy, University of Colorado;

Dr. Charles Feffermann, Professor, Department of Mathematics, Princeton University;

Dr. Richard Muller, Professor, and Senior Faculty Scientist, Department of Physics, Lawrence Berkeley Laboratory, University of California at Berkeley;

Dr. Thomas Pollard, Professor and Director, Department of Cell Biology and Anatomy, John Hopkins University Medical School;

Dr. George Keyworth, Director of Research, Hudson Institute and former Science Advisor to President Reagan;

Dr. William Carey, former Assistant Director, Bureau of Budget;

Dr. Mary Good, President, Engineered Materials Research, Allied-Signal Corporation and Chairman of the National Science Board;

Dr. William Brinkman, Executive Director of Research, AT&T Bell Labs;

Dr. John Waymouth, former Director of R&D, GTE Lighting Products Group; and

Dr. Lawrence Hecht, Executive Director, Iacocca Institute, Lehigh University.

○